

Urban-Rural Land Use Change Detection and Analysis Using GIS & RS Technologies

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Key words: GIS, RS, Urbanization, rural settlement, agricultural lands, land use.

SUMMARY

This paper aims at detecting and analyzing urban-rural land use change, using Remote Sensing (RS) and Geographical Information Systems (GIS). In this context, two multi-temporal studies were conducted in two different sites. The first site includes 3 cities in Morocco (Ksar El Kébir, Khémisset & Béni Mellal), and the second one concerns Al-Ahsa oasis in Saudi Arabia. The main objective was to investigate the effects of urbanization on agricultural lands. The first study was based on 6 images of Spot-HRV (2 for each city) and the second one was based on 2 images of Landsat-TM. The visual interpretation of satellite imagery enabled us to produce three maps of land use categories and the corresponding statistics. The changes occurring respectively during the last 20 years (in Morocco) and 14 years (in Saudi Arabia) were estimated using GIS tools. The over-all changes illustrated in the form of evolution matrix and map proved that urbanization has impacted mainly the agricultural lands due to the speculation practices. In conclusion, RS & GIS technologies together with ancillary data can be used to assist decision makers to prepare future plans, in order to find out appropriate solutions to urbanization encroachment.

RÉSUMÉ

Cet article a pour but ultime de détecter et d'analyser les changements de l'utilisation du sol dans les espaces urbain et rural, en utilisant les nouvelles technologies de télédétection et des Systèmes d'Information Géographique (SIG). Dans ce contexte, deux études multi-temporelles ont été réalisées dans 2 sites. Le premier est formé de 3 villes au Maroc (Ksar El Kébir, Khémisset et Béni Mellal), et le second concerne l'oasis de Al-Ahsa en Arabie Saoudite. Le principal objectif était d'évaluer l'impact de l'urbanisation sur les terres agricoles. La première étude était basée sur 6 images du satellite Spot-HRV (2 par ville), et la seconde étude était basée sur 2 images du satellite Landsat-TM. L'interprétation visuelle des images satellite a permis de produire 3 cartes d'utilisation du sol, ainsi que les inventaires statistiques correspondants. Les changements intervenus respectivement durant les 20 dernières années (au Maroc) et les 14 années (en Arabie Saoudite) ont été estimés au moyen des outils de SIG. Les changements présentés sous forme de matrice et de carte d'évolution, ont prouvé que l'urbanisation a affecté principalement les terres agricoles, dû à la pratique de la spéculation foncière. En conclusion, Les techniques de télédétection et des SIG, de concert avec les données auxiliaires, peuvent être utilisées pour aider les décideurs à élaborer les plans d'aménagement futurs, en vue de trouver les solutions appropriées au contrôle du phénomène de l'expansion urbaine.

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1. INTRODUCTION

Remote sensing along with GIS tools used to gather, display, store, analyze and output data related to the urban and sub-urban environment, can provide planners with certain data sets (Donnay et al., 2001; Bahr, 2001), in order to better manage the urban and sub-urban areas. RS and GIS can be used in particular in:

- location and extent of urban areas;
- spatial distribution of different land use categories;
- primary transportation network and related infrastructure;
- various census-related statistics and socio-economical indicators;
- 3-D structure of urban area for telecommunications and Environmental Impact Assessment (EIA) studies; and
- the ability to monitor the changes in these features over time.

The data set number 1, 2 and 6 can be tackled through land use/cover mapping and land use change detection, using the appropriate techniques of image classification, change detection and analysis. The remaining data sets still require further development to be fully operational.

Urban-rural land use change is a very important phenomenon, which characterizes the urban and sub-urban areas surrounding the cities and oasis in the desert and arid zones, due mainly to urbanization activities, resulting from demographic and industrial development and also from immigration. Urbanization is considered to be an important issue and its impact on the agricultural lands surrounding urban areas has to be studied.

In this context, 2 studies were conducted respectively in the Kingdom of Morocco (Anys et al., 1999a; 1999b) and in the Kingdom of Saudi Arabia (Mufareh, 2002; Ait Belaid and Mufareh, 2002), in order to detect urban land use changes. The main objective was to investigate the effects of urbanization on agricultural lands in 3 cities in Morocco (Ksar El Kébir, Khémisset, and Béni Mellal) and in Al-Ahsa oasis in Saudi Arabia.

The first study was based on 6 panchromatic satellite imagery (2 for each city) acquired by Spot-HRV satellite during two decades, namely 1980, and 90. The second study concerning Al-Ahsa oasis in Saudi Arabia was based on two multispectral satellite imagery of Landsat-TM during two periods of time, namely 1987 and 2001. In the two case studies, topographical maps and current ground observations were also used.

The adopted methodology consisted of four Steps: 1) intensive geographical study; 2) extensive review of land use change detection methods; 3) visual interpretation of the satellite imagery to produce land use maps; and 4) spatial analysis and modeling of the remote sensing results.

2. LAND USE CHANGE DETECTION TECHNIQUES

2.1 Land Use Change Detection Methods

One prerequisite for successful change detection is an accurate registration of satellite imagery, so the overlaid pixels represent the same location. There is a wide range of techniques used for land use change detection of urban areas. These techniques can be subdivided into the following categories: Composite Image; Image Comparison; Comparison of the Classified Images; Combination of the Classified Images; Radar Classification.

2.1.1 Multi-Date Composite Image Method

Images of different periods can be combined to form a new composite single image, in which changes may be inferred from variations in gray tone or color hue. Enhancement procedure most frequently employed for change detection includes image overlay, image differencing, image ratioing, and vegetation index. The role of the enhancement procedure is to suppress areas of no change and enhance areas containing changes. The composite image is then classified. Enhancement procedures can be described as follows (Fung and Zhang, 1989):

- Image Overlay is a combination of 2 images, which are assigned to different colors
- Image Differencing involves subtraction of two images or two bands pixel by pixel
- Image Ratioing is based on the division of bands to generate the rationed image
- Vegetation Index serves to discriminate between vegetation and soil background.

2.1.2 Image Comparison Method

A comparison can be made between separate satellite images for different dates. These images may be single band gray tone or multiple band color composite images. Image variation between dates signals the occurrence of land cover change (Martin, 1989).

2.1.3 Comparison of the Classified Images

Abdellaoui (1997) studied the spatial extension of urban areas in urban complex of Blida and in the oasis of Laghouatt, in Algeria, using satellite data and traditional maps. He pointed out that Blida has expanded 1055 hectares since 1962. A slightly different study was conducted in north-eastern Cairo, in Egypt, using multi-source data, Landsat-TM, Spot-HRV and KVR-1000, with spatial resolution of 30 m, 20 m and 5 m respectively. Over all, the merged images TM-KVR and HRV-KRV provided a higher information content. It was possible to map out land use changes over 48 years (1945, 86, 91, and 93), which offers a valuable indicator for urban growth (CEDARE, 1998). Another investigation was conducted in Rosetta region in Egypt (El-Raey et al., 2000). Only existing urban block maps (for 1917, 45, 63, and 93) were used for the purposes of the study, along with aerial photographs and GIS tools. Another study was made to investigate the trend of urbanization in a large city in south Taiwan (Cheng-Ming et al., 2002). The study was based on 2 images of Landsat-MSS and 2 images of Landsat-TM taken during the periods of 1972, 81, 90 and 2000, along with some social indicators (area of the site, population, population density, employment). Two similar

studies were conducted respectively in the cities of Casablanca (Bencheikroun, 1993) and in Rabat-Salé (Bencheikroun and Layachi, 1993).

2.1.4 Combination of the Classified Images

The methodology was developed by Mongkolsawat and Thirangon (1990) in Yasothon province, in Thailand. The main objective of the study was to develop land cover change detection methodology. It consists of classifying 2 geocoded Landsat-TM imagery acquired during the wet and dry seasons and based on land cover and terrain types. It produced a September image with 11 classes and an April image with 14 classes. The 2 classified images were then mathematically combined resulting in a unique linear combination of 154 possible gray level image. Through a process of regrouping these gray levels into classes, the resultant image provides a meaningful land cover dynamics with respect to the terrain types.

2.1.5 Classification of Radar Imagery

Al-Bilbisi and Tateishi (2002) investigated the performances of land use/land cover classification with textural analysis, using 2 radar satellite imagery JERS-1 (SAR) L-band acquired in October 1993 and March 1995, in north-eastern of Japan. Textural feature (contrast, energy, entropy, and homogeneity) images were generated using SAR L-band 4-look images, for the purpose of supervised classification. The combination of all textural feature images gives the best over-all accuracy result, where 89% and 93% were obtained for 1993 and 1995 respectively. Lee et al. (2002) investigated the use of multi-frequency and multi-polarization SAR data, in the northern of peninsular Malaysia. The classification was based on the physical and statistical properties of the POLSAR data. Focus was placed on the C and L-bands POLSAR data (10 m resolution), provided by NASA/JPL aircraft in 1996. These data were proven to be useful in land cover classification. The use of the combined C and L-bands fully polarimetric data, allows to reach the accuracy of 83%. At present, only single-frequency and single-polarization SAR are available on space platforms such as ERS-1,2; JERS-1; RADARSAT-1. Nevertheless, with the advent of multi-frequency and multi-polarization SAR satellite like the ENVISAT and other upcoming satellites including RADARSAT-2 and ALOS, it will be possible to produce more accurate land cover classifications.

2.2 Land Use Change Analysis and Modeling

A model was applied to the country-level land use/land cover maps produced for north Ningxia, in China, during the period 1987-99. The monitoring of such changes requires the understanding of forces driving changes. This task could be ensured by a multivariate regression modeling, which links the changes in dependant variables (ex. land use changes) with the changes in independent variables (ex. Human activities). This postulates a linear relationship between the dependent and independent variables, which can be represented and processed mathematically (Weicheng et al., 2002). Kaufmann et al. (2000) also investigated the problem of modeling and forecasting effects of land use changes in China based on socio-economical drivers. It is possible to map out land use changes with high accuracy (93.5%), particularly for the ultimate land use categories. The size of developed land tripled between

1988 and 1996. The application of time series econometrics and artificial neural networks improves the monitoring of change and time of change in a series of images. Yang and Lo (2003) have investigated the modeling of urban growth and landscape changes in the Atlanta metropolitan area, using an urban growth model closely coupled with land transition model, in order to simulate future urban growth. The model was calibrated with historical data (1973-1999), extracted from time series of satellite imagery taken during different periods, namely 1973, 79, 87 93 and 99. Three specific scenarios were designed to simulate the spatial consequences of urban growth (2000-2050) under different environmental conditions. Nagai et al. (2002) developed a new methodology to reconstruct long-term land cover changes from fragmentary observational data and knowledge of the changes. Genetic algorithm was used as an interpolation method to create most probable spatial-temporal distribution of land cover categories. The maximum likelihood interpolation model using genetic algorithm was applied in Japan to reconstruct the long-term land cover changes during 1900-90 by 10 years interval.

3. ADOPTED METHODOLOGY

The Methodologies adopted in the two studies are slightly different, but the main steps are similar (Fig.1): geographical study, satellite and ancillary data acquisition, land use mapping using visual interpretation, data analysis and interpretation using GIS.

3.1 Geographical Study

An intensive geographical study was conducted through the existing and available bibliography. It included a description of physical conditions like climate, erosion, land, water, and vegetation; but also the characterization of the impact of human and animal pressures and severe climate conditions. More clearly, the study focuses on urbanization encroachment, population/demography, and agricultural practices in urban-rural fringes.

3.2 Satellite and Ancillary Data Acquisition

In order to perform the study, satellite imagery is required and it has to be available in the catalogue at the appropriate period of time (year, season) and free of clouds. Satellite imagery may be mainly Landsat-TM, Spot-HRV, etc.. Existing cartographic data (topographic maps, road network maps, boundaries) are also necessary to be used in the process of registration and integration with satellite imagery and/or to cover the periods, which are not covered by satellite imagery. Finally, ground observations, and existing statistics are also of great importance in the process of visual interpretation and validation/control of remote sensing results (land use maps).

3.3 Land Use Mapping Using Satellite Imagery

At least, two satellite imagery should be used for each city or oasis, corresponding to two different periods of time. The adopted interpretation technique, which is preferred to the standard classification, is based on photo-interpretation or visual interpretation assisted by computer. The process consists of displaying the rectified/registered imagery on the screen and digitizing polygons representing different land use categories, based on image

characteristics such as tone, texture, color and pattern, which are translated into land use attributes. The whole process is guided by ground observations and local knowledge. These polygons are identified by independent labels attached to the centroid of each polygon. The technique employed for ground truthing aims at localizing and characterizing field observations (land use categories, delimitation of classes) using Global Positioning System (GPS) facilities.

The result of the visual interpretation technique, in this study, is a digital coverage layer, in which polygons represent different land use categories. A full database is attached to this coverage, in which every polygon is characterized by many attributes like, the category number, area and perimeter of polygons. The land use maps produced at each period, at a scale of 1/50000 or 1/100000 includes 7 to 8 thematic classes or categories, depending on the characteristics and objectives of the study site.

3.4 Data Analysis and Interpretation Using GIS

As input, we use the results of remote sensing (Parag. 3.3.), which include land use map and the corresponding statistical inventory produced for each period. Firstly, we can realize the pair-wise comparison of land use maps, as well as their statistical inventories, in order to detect changes in terms of area but also the geographic location of these changes. Secondly, urban and sub-urban areas can be identified and assessed, in order to produce the evolution map between two periods only for urban and sub-urban. Thirdly, by keeping in all land use categories, we can investigate the impact of urbanization on other land uses and vice-versa. Finally, the “evolution matrix” is built-up for two periods, providing all possible changes involved and the corresponding areas in terms of extension, regression and neat evolution for all categories. The same result can be illustrated by an over all evolution map.

4. DATA ANALYSIS AND RESULTS OBTAINED

The adopted methodology and the obtained results will be presented, according to two case studies, conducted respectively in the Kingdom of Morocco and the in Kingdom of Saudi Arabia.

4.1 Case Study in the Kingdom of Morocco

4.1.1 Context

The main objective was the assessment of urbanization impact on agricultural lands in the 3 cities of Ksar El Kébir, Béni Mellal, and Khémiset (Fig. 2a) during the last three decades (1970, 80 and 90), in order to protect agricultural lands from urbanization expansion, through the elaboration of an urban planning director scheme (Shéma Directeur d'Aménagement Urbain). Each study site covers a square of 30 km by 30 km centered on each of the cities. In terms of satellite data, 2 panchromatic Spot-HRV imagery with 10 m spatial resolution were used to cover the last two decades (1980 and 90). In addition, topographic city maps were used to cover the first decade (1970). Ground observations were used to complete the process of validation and control of land use mapping.

4.1.2 Data Analysis

For each city, we performed the following operations:

- land use mapping using ancillary data and GIS for digitizing city maps at a scale of 1/10000 for 1970 decade (which are available only for two cities).
- Pre-processing of two panchromatic Spot-HRV imagery which consists at image subsetting, geometric correction and registration according to the parameters of the national reference system (Clarck' 1880 projection and Merchich Datum).
- land use mapping by photo-interpretation, using two panchromatic Spot-HRV imagery acquired during the 1980 and 90 decades;
- analysis and interpretation of the three land use maps, using GIS for analyzing the changes of land uses and modeling their mutual impacts.

4.1.3 Results and Discussion

The results and findings outlined from of the case study in Morocco are discussed in the paragraph below (Anys et al., 1999a; 1999b):

Detailed land use maps, at a scale of 1/50000, offering an extensive diagnosis of land use categories in terms of areas at each decade (1970, 80 and 90). The adopted typology includes the following classes, urban areas, rural settlements, fruit trees, rain-fed crops, irrigated crops, rangelands, forests and water bodies. The total area of each site is 90000 ha.

Evolution maps for the three intervals of time (1970-80, 80-90 and 70-90), illustrating the temporal evolution and trends of land use categories. In twenty years, urban areas were increased by 598 ha (344%) in the city of Ksar El Kébir (Fig. 2b), and by 981 ha (180%) in Béni Mellal, while rural settlements were increased by 1945 ha (160%) in Ksar El Kébir (Fig. 2b) and 756 ha (200%) in Béni Mellal. For the city of Khémisset (for which there was no city map available for the 1970 decade), the ten years extension was 648 ha (70%) for urban areas and 363 ha (60%) for rural settlements. It is noticed that the most urban changes occur during the recent years (1980-90), compared to the older period of time 1970-80.

Impact assessment of urbanization on agricultural lands and other classes, in terms of extension, regression and neat evolution for Ksar El Kébir city. The evolution matrix generated for the whole interval 1975-96 (Table 1) signals the major land use changes. Furthermore, it illustrates quantitatively the land use categories, which are impacted by any change and vise-versa. During the last 20 years, urban areas have expanded 598 ha, from which 501 ha were converted from rain-fed crops, 62 ha from rural settlements and 19 ha from fruit trees. Rural settlements areas have increased tremendously by 1945 ha, from which 1372 ha were taken from rain-fed crops, 520 ha from rangelands and 61 ha from fruit trees. We can conclude that urban growth and rural settlements are severely impacting agricultural lands (rain-fed crops, fruit trees, rangelands). We can notice as well the increase of the area of water bodies by 1457 ha, and the area of irrigated crops by 12917 ha which correspond respectively to the construction of a new dam and the development of a new irrigation plan in the region between 1970 and 80.

The cartographical and statistical results are powerful tools, regarding the protection of agricultural lands. Furthermore, these results are necessary to fulfill the requirements of urban planning (Urban Planning Director Scheme) and zoning. The cost of the study estimated at 18 \$US/km² and the delivery time of 8 months will encourage/facilitate the application of the methodology and extend studies to other cities in Morocco.

4.2 Case Study in the Kingdom of Saudi Arabia

4.2.1 Context

Al-Ahsa is one of the biggest oases in Saudi Arabia (Fig. 3a). It includes the three cities of Hufuf, Mubarraz and Al-Youn. The design/shape of the three cities have been changed consistently during the last 30 years, especially with the development of oil industry since 1970's (Mufareh, 2002; UNEP, 2002), and as a consequence the development of valuable utilities and services. The population in Al-Ahsa oasis is estimated at 800000 inhabitants (due to population growth and immigration), from which 78% living in urban areas and 22% in rural areas and villages. The main activity is concentrated in the agricultural sector (palm trees, etc..), but the agricultural area is declining, due to climatic and anthropogenic factors, such as sand movement, urbanization encroachment, decrease of the level of ground water table, lack of drainage (sabkha), due to speculation practices and the small size of agricultural parcels/plots, which can not be exploited cost-effectively. The climate is arid, the mean temperature is ranging from 26 to 27° C while the precipitation is ranging from 75 to 110 m. We noticed also a sand movement/drift coming from the north-west and north direction, estimated at 3 m³/m width.

The study site covered a rectangle of 40 km by 55 km centering on Al-Ahsa oasis. Two multi-spectral Landsat-TM imagery, with 30 m spatial resolution, were used to cover the two periods of October 1987 and 2001. Topographic maps at a scale of 1/25000 and road network map were also used, along with ground observations.

4.2.2 Data Analysis

For Al-Ahsa oasis, we performed the following operations:

- Pre-processing of two Landsat-TM imagery which consisted of image subsetting, geometric correction and registration according to the parameters of the national grid reference (UTM projection, WGS'84 Datum and Zone 39).
- land use mapping by photo-interpretation, using ground observations and two Landsat-TM imagery, taken during the two periods 1987 and 2001
- Analysis and interpretation of the two land use maps produced in the former step, using GIS, in order to investigate the impact of urbanization on other land uses.

4.2.3 Results/Discussion

The results and findings outlined from of the case study in Saudi Arabia are discussed in the paragraph below (Mufareh, 2002; Ait Belaid and Mufareh, 2002):

Detailed land use map at a scale of 1/100000, offers an extensive diagnosis of urban and sub-urban areas at each period (1987 & 2001). The land use categories include the following classes, urban areas, urban planning, agricultural lands, sabkha, sand dunes, hills and water bodies. The total area of the study site is approximately 222000 ha.

One evolution map for the period from 1987 to 2001, illustrates the temporal evolution and trends for land use categories. In Al-Ahsa oasis during 14 years, urban areas (Fig. 3b) have been expanded by 5326 ha (75%) and agricultural areas by 4430 ha (22%). During the same period of time, there was a decrease in the areas of sabkha by 8063 ha (12%), urban planning by 1341 ha (27%), sand dunes by 206 ha and hills by 146 ha.

Impact assessment of urbanization on agricultural lands and other categories, in terms of extension, regression and neat evolution was conducted for Al-Ahsa oasis. The evolution matrix generated (Table 2) illustrates the major land use changes occurred. It signals also the land use categories, which are impacted by any change and vise-versa. During 14 years, urban areas have increased by 5326 ha, from which 2746 ha were converted from sabkha, 1500 ha from urban planning, 972 ha from sand dunes and 513 ha from agricultural lands. At the opposite side, agricultural lands have increased by 4430 ha, from which 4480 ha converted from sabkha, 1654 ha from sand dunes, 184 ha from urban planning and 119 ha from urban areas. The agricultural lands experience many transformation, because we have at the same time a great extension of 6520 ha and a regression of 2090 ha. Over-all, urban areas and agricultural lands have known a neat evolution. This expansion was compensated by the neat regression of other land use categories, sabkha (8063 ha), urban planning (1341 ha), sand dunes (206 ha) and hills (146 ha). This means that, new sand dunes, new Sabkha, new urban planning were developed, but at the same time these new areas were consumed by urban areas and agricultural lands. In conclusion, Al-Ahsa oasis is facing many problems, related to urbanization extension, deterioration of agricultural lands, formation of new sabkha and new sand dunes. These findings confirm the hypothesis of the geographical study.

Overlay of the evolution map and road network map to localize the urban changes and directions. The cartographical and statistical results are valuable tools for the protection of agricultural lands and planning of urban areas in the oasis fragile environment. The cost of the study was estimated at only 9 \$US /km² and the delivery time at 4 months.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The findings after the application of the methodology in the two studies are as follows:

In terms of scale, with Spot-HRV (10 m) we are able to produce land use maps at an equivalent scale of 1/50000, while with Landsat-TM (30 m) the equivalent scale is 1/100000. Consequently, the accuracy of land use maps produced depends on their scales.

In terms of number of periods of time, in Moroccan's site we considered three periods providing a cumulative period of more than 20 years and many possibilities of land use analysis (3 pair-wise comparisons), while in Saudi Arabia site, we considered only two periods summarizing 14 years (only 1 pair-wise comparison).

The dimension of the study site is also an important factor, 30 km by 30 km in the case of Moroccan cities, and 40 km by 55 km for Al-Ahsa oasis, due to the nominal dimension of satellite imagery. It depends also on our interest in investigating urban areas as well as rural settlements to understand the relationships between the urban cities and the rural settlements.

The typology or the number of land use categories depends on the site itself and the objectives of the study. The thematic classes varies from Moroccan to Saudi sites.

The over-all evolution matrix is very adequate and very informative. Practically, it gives the areas of all possible changes, but it is applicable only for two periods at ones. So, if we consider 3 periods of time, we need to generate 3 matrices, and if we consider only 2 periods, we need only 1 matrix.

Laboratory facilities are also similar, in terms of GIS and RS software (ArcInfo, and Erdas Imagine). In terms of cost, the study in Saudi Arabia is cheaper (9 \$US /km²) and faster (4 months) than the one in Morocco (which is double in terms of cost and time).

5.2 Recommendations

Recommendations to be drawn from the two studies are as follows:

- Development of urban databases for major cities and oasis based on the results and products of the two studies, along with existing and historical data.
- Updating the urban database using GIS and RS systematically (every 5 years for example) to detect the new changes, which depend mainly on the frequency and occurrence of urban changes and the socio-economical development of the cities/oasis.
- Adoption of an appropriate urban planning and zoning with impact studies and scenarios, in order to protect agricultural lands from urbanization encroachment, sand drift, etc..
- Further developments are still needed in terms of land use change detection and modeling.

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BIOGRAPHICAL NOTES

Bachelor's degree in Surveying (1979) from IAV Hassan II institute in Morocco. Master's degree in Geodesy (1986) and Ph.D. degree in Remote Sensing (1990) from Laval University in Canada. Beginning of the career was with the Ministry of Agriculture (ORMVAD) and involvement in the studies of one of the largest irrigation schemes in Morocco from 1979 until 1992. In 1992, Head of Department of Natural Resources and Environment, at the Royal Center for Remote Sensing (CRTS), coordination of a multi-disciplinary team, carrying out many projects (WATERMED, CAMELEO, MAMORA, AGRIMA) and training programs. Organization of four Symposia in Morocco MARISY'92, 95 and 2000 and EURISY'97. In 1997, elected to the position of Vice-Chairman of the U.N. Committee on the Peaceful Uses of Outer Space (COPUOS), at Vienna. Also appointed to the position of Rapporteur General of the U.N. International Conference, UNISPACE III in 1999. From 2000 until now, holder of His Highness Shaikh Hamad Bin Khalifa Al-Thani's Chair of GIS/RS at The Arabian Gulf University (AGU) in Bahrain. Development of new educational program on GIS/RS. Member of the Global Environmental Outlook (GEO) team; also elected as member of the Millennium Ecosystem Assessment (MA) since 2003. Member of the Organizing Committee of the International Conference GIS'2002 and GIS'2004 in Bahrain. Author and co-author of more than 40 Publications, 10 notes related to projects, 2 brochures with FAO, 2 books with the International Funds for Agricultural Development (IFAD) and the University of Valencia.

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Table 1: Land Use Changes (Evolution Matrix) for Ksar El Kébir During 1975-1996.

1975 1996	Ua	Rs	Fa	Ft	Rg	Wb	Rf	Ig	Extension	Evolution (Ext - Reg)
Ua	---	61.7	0	18.8	0	0	501.4	16.2	598.1	+598.1
Rs	0	---	5.1	61.7	52.4	0	1371.6	48	2006.8	+1945.2
Fa	0	0	---	9.2	176.5	0	1051.8	0	1237.5	+763.1
Ft	0	0	0	---	218.9	0	510.4	0	729.3	-267.1
Rg	0	0	469.3	0	---	0	650.9	0	1120.2	-82.9
Wb	0	0	0	315.2	0	---	1141.4	0	1456.6	+1456.6
Rf	0	0	0	252.5	0	0	---	0	252.5	-17329.6
Ig	0	0	0	339	287.3	0	12354.6	---	12980.9	+12916.6
Regression	0	61.7	474.4	996.4	1203.1	0	17582.1	64.2	xxx	xxx

Ua: Urban Areas

Rs: Rural Settlements

Fa: Forest Areas

Ft: Fruit Trees

Rg: Rangelands

Wb: Water Bodies

Rf: Rain-fed Crops

Ig: Irrigated Crops

Unit: Hectares

Table 2: Land Use Changes (Evolution Matrix) for Al-Ahsa Oasis During 1987-2001.

1987 2001	Ua	Ag	Wb	Hl	Sb	Up	Sd	Extension	Evolution (Ext - Reg)
Ua	---	513.1	1.5	21.5	2745.9	1499.8	972.3	5754.1	+5325.8
Ag	1193	---	---	82.4	4480.4	184.3	1654.1	6520.7	+4430.3
Wb	6.4	---	---	---	---	---	1.9	8.3	+2.0
Hl	15.7	1.4	---	---	197.9	---	---	215	-146.4
Sb	221.2	1396	---	257.5	---	533.3	4368.5	6776.5	-8063.4
Up	14.1	22.1	---	---	193.1	---	827	1056.3	-1341.7
Sd	51.6	157.8	4.8	---	7222.6	180.6	---	7617.4	-206.4
Regression	428.3	2090.4	6.3	361.4	14839.9	2398	7823.8	xxx	xxx

Ua: Urban Areas

Ag: Agricultural Lands

Wb: Water Bodies

Hl: Hills

Sb: Sabkha

Up: Urban Planning

Sd: Sand Dunes

Unit: Hectares

Extension: Increase of the area

Regression: decrease of the area

Evolution : Extension – Regression

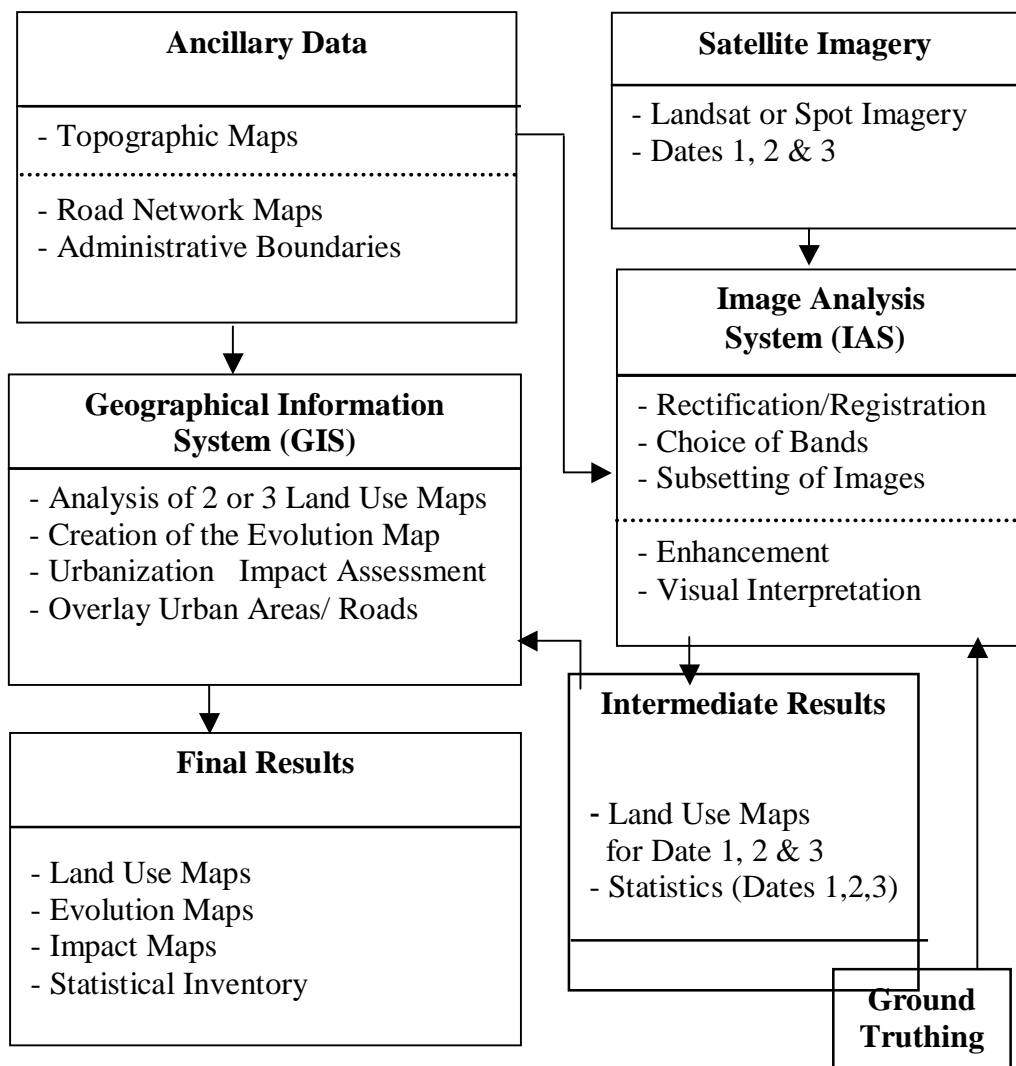


Figure 1: Methodological flowchart used for data input, output and processing.

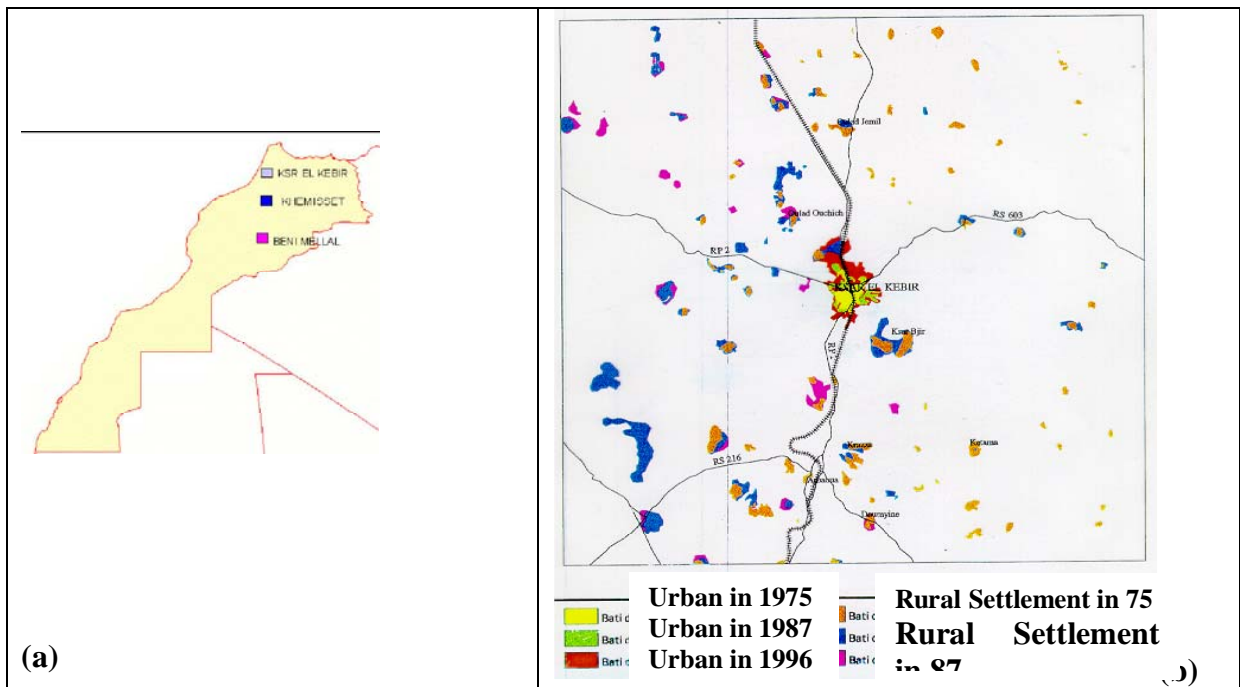


Figure 2: a) Study sites in Morocco; b) Evolution map of urban areas and rural settlements for the city of Ksar El Kébir during 1975, 87 & 96.

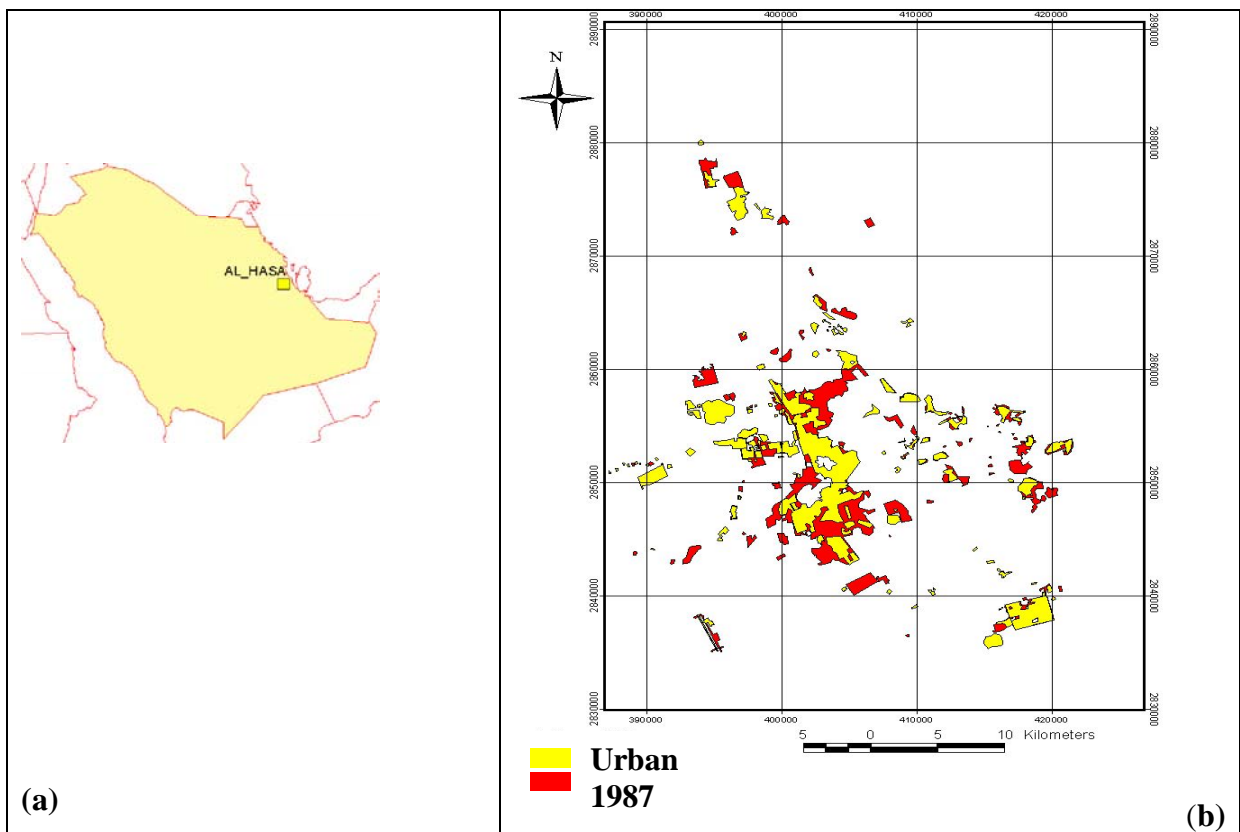


Figure 3: a) Study site in Saudi Arabia; b) Evolution map of urban areas in Al-Ahsa oasis during 1987 and 2001.